Statement of
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U.S. Department of Energy
before the
Subcommittee on Energy
Committee on Science
U.S. House of Representatives
April 27, 2005

Chairman Biggert and Members of the Subcommittee:

Thank you for the opportunity to testify today about the Office of Science's Fiscal Year (FY) 2006 budget request. I am deeply appreciative of your support for basic research, Madame Chairman, and the support we have received from the other Members of this Subcommittee. I am confident that our FY 2006 request represents a sound investment in our Nation's future. Through this budget we will position the Office of Science to be ready for the opportunities of the next decade.

This budget, Madame Chairman, will enable thousands of researchers located across our Nation to work on some of the most pressing scientific challenges of our age. These researchers will demonstrate the scientific and technological feasibility of creating and controlling a sustained burning plasma to generate energy through participation in ITER (Latin for *the way*, ITER is an international fusion collaboration); use advanced computation and modeling tools to resolve complex scientific problems; restore U.S. leadership in neutron science with the start of operations at the Spallation Neutron Source (SNS); expand the frontier of nanotechnology through operation of Nanoscale Science Research Centers (NSRCs); pursue an understanding of how the universe began; contribute to our understanding of climate change including the potential of carbon sequestration; develop the knowledge that may enable us to harness microbes and microbial communities to improve energy production and environmental remediation; and contribute basic research that underpins the President's Hydrogen Fuel Initiative.

The Office of Science requests $3,462,718,000 for the FY 2006 Science appropriation, a decrease of $136,828,000 from the FY 2005 appropriation, for investments in basic research that are critical to the success of Department of Energy (DOE) missions in national security and energy security; advancement of the frontiers of knowledge in the physical sciences and areas of biological, environmental, and computational sciences; and provision of world-class research facilities for the Nation's science enterprise (see Figure 1).

The Office of Science, within a period of budget stringency, has chosen its priorities so that the U.S. will continue its world primacy in science. We have made the hard decisions that will enable our scientists to work on the finest machines whose scale and magnitude will give them opportunities not found elsewhere. As a consequence, we have made difficult choices. But these have been taken with one end in mind: the Office of Science will support a world-class program in science and energy security research with this budget.

This budget request supports the following programs: Basic Energy Sciences, Advanced Scientific Computing Research, Biological and Environmental Research, High Energy Physics, Nuclear Physics, Fusion Energy Sciences, Science Laboratories Infrastructure, Science Program Direction, Workforce Development for Teachers and Scientists, and Safeguards and Security.

The Office of Science supports research across the scientific spectrum from high energy physics to biology and environmental research; from fusion energy sciences to nuclear physics, from basic energy sciences to advanced scientific computation research. We provide 42 percent of the federal funding for the physical sciences in the United States, and are the stewards of support for fields such as high energy physics, plasma physics, catalysis, and nuclear physics. We build and operate the large scientific facilities used by over 19,000 faculty, students, and postdocs each year. They include synchrotron light sources, neutron sources, high energy and nuclear physics accelerators, fusion energy experiments, dedicated scientific computing resources, specialized environmental research capabilities, the Production Genome Facility, and will soon include the SNS, five NSRCs, and an X-ray free electron laser light source. Roughly half of our budget goes to the construction and operation of these facilities; the other half is split, roughly equally, between research at the DOE laboratories and research at universities. This supports the research of approximately 23,500 students, postdocs, and faculty throughout our Nation.

OFFICE OF SCIENCE

FY 2006 PRESIDENT'S REQUEST

(B/A in thousands)

	FY 2004 Comparable Approp.	FY 2005 Comparable Approp.	FY 2006 President's Request
Basic Energy Sciences	991,262	1,104,632	1,146,017
Advanced Scientific Computing Research	196,795	232,468	207,055
Biological and Environmental Research	624,048	581,912	455,688
(Congressionally-directed projects)	*(136,798)*	*(79,608)*	*(——)*
(Core Biological and Environmental Research)	*(487,250)*	*(502,304)*	*(455,688)*
High Energy Physics	716,170	736,444	713,933
Nuclear Physics	379,792	404,778	370,741
Fusion Energy Sciences	255,859	273,903	290,550
Science Laboratories Infrastructure	55,266	41,998	40,105
Science Program Direction	150,277	153,706	162,725
Workforce Development for Teachers and Scientists	6,432	7,599	7,192
Safeguards and Security	56,730	67,168	68,712
Small Business Innovation Research/Technology Transfer	114,915	——	——
Subtotal, Science	3,547,546	3,604,608	3,462,718
Use of prior year balances	-11,173	-5,062	——
Total Science	3,536,373	3,599,546	3,462,718
(Total, excluding Congressionally-directed projects)	*(3,399,575)*	*(3,519,938)*	*(3,462,718)*

Figure 1

FY 2006 SCIENCE PRIORITIES

In his testimony before the House Science Committee, the President's Science Adviser, Dr. Jack Marburger indicated, "Making choices is difficult even when budgets are generous. But tight budgets have the virtue of focusing on priorities and strengthening program management. This year's R&D budget proposal maintains levels of funding that allow America to maintain its leadership position in science and move ahead in selected priority areas."

The priorities the Office of Science has set within the overall Federal R&D effort and in support of DOE's mission are clear: Through the FY 2006 Budget, we will fully support Presidential initiatives in fusion and hydrogen; we will continue strong support for other Administration priorities such as nanotechnology and information technology; we will complete—on time and within budget—unique scientific facilities that will maintain and enhance research in areas we believe offer the greatest potential for broad advances in future energy technologies. These scientific facilities were prioritized in our 20-year facilities outlook, announced in November 2003.

We will continue moving ahead with our contributions to the President's Hydrogen Fuel Initiative. We are supporting U.S. participation in the ITER project to pursue the potential of energy from fusion.

One of the biggest science stories of the year 2006 will be the start-up of the Spallation Neutron Source at our Oak Ridge National Lab, which will provide the most intense—by an order of magnitude—neutron beam in the world for cutting-edge research.

The FY 2006 budget will also bring four of our five nanoscale science research centers on line, providing tools found nowhere else in the world for exploration at the atomic level, offering huge potential for the discovery of entirely new ways to build materials.

We are fully funding construction of the Linac Coherent Light Source at the Stanford Linear Accelerator Center, a machine that will produce x-rays 10 billion times brighter than any existing x-ray source on Earth. When it comes on line in 2009, it essentially will allow stop-action photography of atomic motion. Just ask the pharmaceutical industry what they could do with a machine that shows them how the chemical bond forms *during* a chemical reaction.

The Office of Science also will fully fund the National Energy Research Scientific Computing Center, a key center for capacity supercomputing used by roughly 2,000 researchers every year, and a separate open-access leadership class computing facility at Oak Ridge, focused on providing the capability to carry out a limited number of massive simulations not possible on any other civilian supercomputer in the U.S.

The Department will also expand research underpinning biotechnology solutions to the world's energy challenges and research supporting the President's climate change science program.

Our research programs in high energy physics continue to receive strong support. We have increased funding for future accelerators such as the Large Hadron Collider, scheduled to begin operation in 2007, and the proposed International Linear Collider, which is now in an early R&D phase. Our nuclear physics program will continue to offer world-class facilities for use by thousands of researchers from around the world.

SCIENCE ACCOMPLISHMENTS

The Office of Science has proven its ability to deliver results over the past 50 years. That legacy includes 70 Office of Science sponsored Nobel Laureates since 1954. Our science has spawned entire new industries, including nuclear medicine technologies that save thousands of lives each year, and the nuclear power industry that now contributes 20 percent of the power to our Nation's electricity grid. It has also changed the way we see the universe and ourselves; for example—by identifying the ubiquitous and mysterious "dark energy" that is accelerating the expansion of the universe and by sequencing the human genome. The Office of Science has taken the lead on new research challenges, such as bringing the power of terascale computing to scientific discovery and industrial competitiveness. The Nation's investment in SC's basic research programs continues to pay dividends to the American taxpayer. Some of the past year's highlights include:

- *Promoting Science Literacy and Fostering the Next Generation of DOE Scientists.* In FY 2004, DOE launched a seven-part program named STARS: Scientists Teaching and Reaching Students. This program is designed to enhance the training of America's mathematics and science teachers; boost student achievement in science and math, especially in the critical middle school years; and draw attention to the women and men who have done DOE science so very well—and thereby encourage young people and prospective teachers to pursue careers in math and science. STARS is a critical step in leveraging the resources of DOE—and of all our national laboratories—to help create a new generation of scientists who will achieve the scientific breakthroughs and technological advances so essential to our future security and prosperity.

- *Nobel Prize in Physics.* The 2004 Nobel Prize in physics was awarded to David J. Gross (Kavli Institute, UC Santa Barbara), H. David Politzer (Caltech), and Frank Wilczek (MIT) for their discovery of "asymptotic freedom" in the strong force. What they discovered was a surprising fact: as fundamental particles get closer to each other, the strong force between them grows weaker, and the further apart they are, the stronger it is, like stretching a rubber band. This discovery is a key component of the very successful Standard Model of particle physics, which describes three of the four fundamental forces of nature: electromagnetic, weak, and strong. Physicists dream of extending the theory to include the fourth fundamental force, gravity. The Office of Science has supported the research of Wilczek since the 1980's at Princeton and the Massachusetts Institute of Technology (MIT) and has supported Politzer at Caltech from the 1970's.

- *Nobel Prize in Physics.* The 2003 Nobel Prize for Physics was shared by Argonne National Laboratory (ANL) researcher Alexei A. Abrikosov for his pioneering contributions to the theory of superconductors. The Office of Science has long supported Abrikosov's work on the mechanisms of high temperature superconductivity. Amongst the myriad applications of superconducting materials are the magnets used for magnetic resonance imaging, or MRI, and potential applications in high efficiency electricity transmission and high-speed trains.

- *New Physics Emerges From Quark-Gluon Plasma.* In 2004, the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory (BNL) delivered gold beams at twice the accelerator design limits and greatly exceeded the expectations of the 1,000-plus international physicists working on the four experiments at RHIC. The goal of RHIC is to recreate the predicted quark-gluon plasma, an extremely dense state of matter thought to have last existed microseconds after the Big Bang. RHIC has announced evidence of a quark-gluon state of matter at high density and temperature, exhibiting the properties of a highly correlated liquid —something new and unexpected— as well as indications of a dense, weakly interacting gluonic matter that has been called a "Color Glass Condensate"—again something new.

- *Wide Acceptance of Open-Source, High-End Cluster Software by Industry and Users*. The Oak Ridge National Laboratory (ORNL) Open Source Cluster Application Resources (OSCAR) computing software for high-end computing continues to expand its capability and to increase its user base. The software has been downloaded by more than 130,000 groups around the world and is promoted by vendors such as Dell and Intel. The adoption of this system has expanded the number of software packages available to the cluster community, and continues to reduce cluster total cost of ownership. It has simplified the job of software authors, system administrators, and ultimately the application user by providing a timely and much simpler method of supplying and applying software updates. The Scientific Discovery through Advanced Computing (SciDAC) Scalable Systems Software Integrated Software Infrastructure Center leverages OSCAR technology to simplify deployment for the end-user as well as application developers.

- *Advances in Fusion Energy Sciences Contribute to ITER.* Efficient burning of the fusion's plasma fuel, a mixture of hydrogen isotopes, requires stably confining the plasma at temperatures of 50-100 million degrees, comparable to those found on the Sun, with magnetic fields designed to hold the plasma in place. Recent application of diagnostics that can measure the magnetic fields deep *inside* this highly energetic plasma with great precision and advanced computer codes that can model the detailed behavior of the plasma has given scientists unprecedented control over the behavior of the plasma. Experiments on the DIII-D tokamak have led the way in prototyping future experiments on ITER. Scientists are now able to use feedback control systems to confidently operate the plasma at pressures which optimize the fusion power output within a given magnetic field. In addition, experiments and the use of massively parallel computing to benchmark models that validate a whole new theoretical understanding of how plasmas can be insulated from loss of particles and energy give confidence that ITER can achieve the needed gain of 10 (50 Megawatts of heating, 500 Megawatts of fusion power production) required to enter the burning plasma regime.

- *Using DOE Technology and Know-how to Bring Sight to the Blind.* DOE's artificial retina project is a model for success in an era when the boundaries of scientific disciplines, public and private sector roles in science, and federal agency responsibilities are increasingly blurred. Success has come through the strength of partnerships between scientists in the public and private sectors, spanning scientific disciplines from materials to medicine to engineering to surgery, and with funds from both DOE and the National Institutes of Health (NIH). In June 2004, the project reached a major milestone as a sixth blind patient was successfully implanted with an artificial retina device. One patient has had the device since February 2002. All six patients can now read large letters (2 foot large letters one foot away) as well as tell the difference between a paper cup, a plate, and a plastic knife. The patients can also see colors although learning and understanding this process is still a challenge for both patients and scientists. Patients will soon begin using their retinal implants outside the laboratory and will even be able to use them alone at home. These initial patient studies are a key part of a Food and Drug Administration Investigational Device Exemption trial.

- *Record Operations Advance Physics at the Frontier.* Both the Fermi National Accelerator Laboratory (Fermilab) and the Stanford Linear Accelerator Center (SLAC) set significant new records in data delivery ("luminosity") in 2004, with the accelerators at each of these centers more than doubling their outstanding performance levels from 2003. On Friday, July 16, the Tevatron proton-antiproton collider at Fermilab set a new luminosity record of $1x10^{32}$ $cm^{-2}sec^{-1}$. The use of the Recycler and Accumulator together to maximize the number of antiprotons available for collisions helped to set the new record. Since January 2004, the peak luminosity of the Tevatron has increased 100 percent. The FY2004 PEP-II/Babar run at SLAC ended as scheduled on July 31, setting new performance records. Since the SLAC facility for B meson research began operations in 1999, its accumulated total number of electron-positron collisions (integrated luminosity) has steadily increased to a level about five times higher than the design performance.

PROGRAM OBJECTIVES AND PERFORMANCE

Underpinning all of SC's programs is a fundamental quest for knowledge. Our program history provides a compelling story of how this knowledge has already shaped the world around us, and the future appears even more promising.

DOE's Strategic Plan identifies four strategic goals (one each for defense, energy, science, and the environment) and seven subordinate general goals. The Office of Science supports the Science Goals. Detailing Office of Science contributions to DOE's Science goals are 27 annual performance goals. Progress toward the annual goals is tracked quarterly through the Department's Joule system and reported to the public annually through the Department's Performance and Accountability Report (PAR).

The one Office of Science annual performance goal that was not met in FY 2004 was: "Focus usage of the primary supercomputer at the NERSC on capability computing. 50 percent of the computing time used will be accounted for by computations that require at least 1/8 of the total resource." The allocation process for NERSC resources is based on the potential scientific impact of the work, rather than on how well the work scales to large numbers of processors. When we proposed this measure we did not understand the extent to which users who run large jobs also run small jobs. It is critical for users to be able to run their software at both scales on the same computer because it significantly simplifies their software management. Therefore we are reducing the percentage of time dedicated to large jobs at NERSC to 40 percent. In addition, we have tasked the NERSC Users Group to develop science-based measures to better assess NERSC performance.

As a basic research program, the meaning and impact of our performance goals may not always be clear to those outside the research community. The Office of Science has created a website (www.sc.doe.gov/measures) to better communicate what we are measuring and why it is important. We are committed to improving our performance information and will soon be expanding the information included on the website and simplifying the interface so that the program objectives and results will be accessible to a wide audience.

ORGANIZATION

The OneSC Project was initiated to streamline the Office of Science structure and improve operations across the Office of Science complex in keeping with the principles of the President's Management Agenda. The first phase of this multiphase effort is now complete and we have realigned the Office of Science organization structure to establish a clear set of integrated roles and responsibilities for all Headquarters (HQ) and Field elements (Figure 2). Policy direction, scientific program development and management functions were defined as HQ responsibilities. Program execution, implementation, and support functions were defined as Field responsibilities. The major structural change implemented is the removal of a layer of management from the Office of Science Field structure, in effect removing the layer that existed between the Office of Science Director and the Site Office Managers located at Office of Science laboratories. In addition, the Chicago Office will now serve as the personnel office for Office of Science employees in HQ. The second phase of the OneSC initiative will entail a reengineering of our business processes and is in the preliminary stages of development.

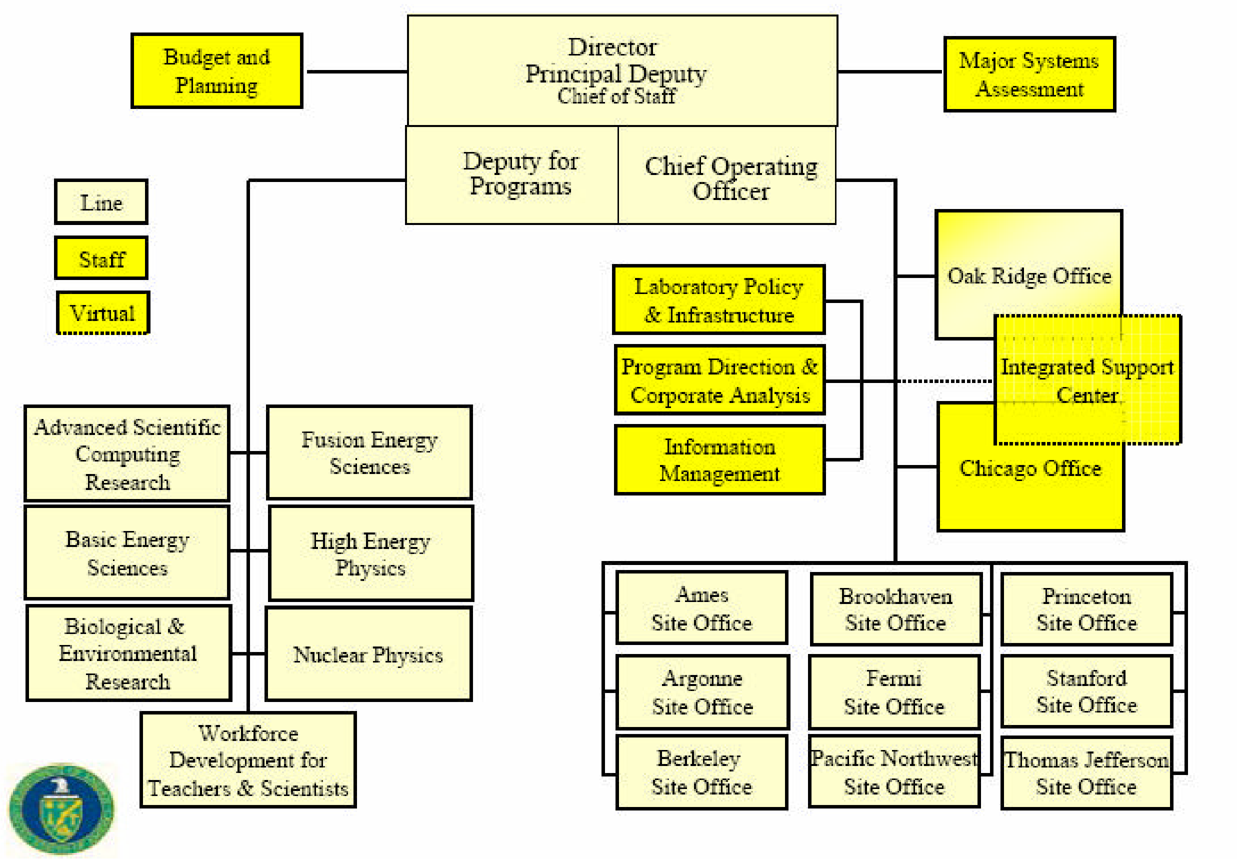

Figure 2

SCIENCE PROGRAMS

BASIC ENERGY SCIENCES

FY 2005 Comparable Appropriation - $1,104.6 Million; FY 2006 Request - $1,146.0 Million

The Basic Energy Sciences (BES) program advances nanoscale science through atomic- and molecular-level studies in materials sciences and engineering, chemistry, geosciences, and energy biosciences. BES also provides the Nation's researchers with world-class research facilities, including reactor- and accelerator-based neutron sources, light sources soon to include the X-ray free electron laser, nanoscale science research centers, and micro-characterization centers. These facilities provide outstanding capabilities for imaging and characterizing materials of all kinds from metals, alloys, and ceramics to fragile biological samples. The next steps in the characterization and the ultimate control of materials properties and chemical reactivity are to improve spatial resolution of imaging techniques; to enable a wide variety of samples, sample sizes, and sample environments to be used in imaging experiments; and to make measurements on very short time scales, comparable to the time of a chemical reaction or the formation of a chemical bond. With these tools, we will be able to understand how the composition of materials affects their properties, to watch proteins fold, to see chemical reactions, and to understand and observe the nature of the chemical bond. Theory, modeling, and computer simulations will also play a major role in achieving these outcomes and will be a companion to experimental work. Also supported is basic research aimed at advancing hydrogen production, storage, and use for the coming hydrogen economy.

FY 2006 will mark the completion of construction and the initial operation of the Spallation Neutron Source (SNS). The SNS will be significantly more powerful (by about a factor of 10) than the best spallation neutron source now in existence—ISIS at the Rutherford Laboratory in England. We estimate the facility will be used by 1,000-2,000 scientists and engineers annually from academia, national and federal labs, and industry for basic and applied research and for technology development. The high neutron flux (i.e., high neutron intensity) from the SNS will enable broad classes of experiments that cannot be done with today's low flux sources. For example, high flux enables studies of small samples, complex molecules and structures, time-dependent phenomena, and very weak interactions. The FY 2006 budget authority request completes funding for the SNS Project. This will involve procurement and installation of equipment for instrument systems, completion of an accelerator readiness review, commissioning of ring and target systems, and meeting all requirements to begin operations; and all SNS facilities will be turned over to operations. The estimated Total Project Cost remains constant at $1,411,700,000.

Operations will begin in FY 2006 at four of the five NSRCs: the Center for Nanophase Materials at ORNL, the Molecular Foundry at Lawrence Berkeley National Laboratory (LBNL), the Center for Integrated Nanotechnologies at Sandia National Laboratories/Los Alamos National Laboratory (SNL/LANL), and the Center for Nanoscale Materials at ANL. The exception is the Center for Functional Nanomaterials at BNL, which is scheduled to begin operations in FY 2008. The NSRCs are user facilities for the synthesis, processing, fabrication, and analysis of materials at the nanoscale. They are designed to promote rapid advances in the various areas of nanoscale science and technology and are part of the DOE contribution to the National Nanotechnology Initiative. The NSRCs are sited adjacent to or near existing BES synchrotron or neutron scattering facilities to enable rapid characterization of newly fabricated materials. FY 2006 funds are requested for construction of NSRCs located at LBNL, at SNL/LANL, and at BNL. Funds are also requested to complete the Major Item of Equipment (MIE) for the NSRC at ANL

The Linac Coherent Light Source (LCLS) will continue Project Engineering Design (PED) and FY 2006 budget authority is requested to initiate physical construction of the LCLS conventional facilities. Funding will be provided separately for preconceptual design of instruments for the facility. BES funding will also be provided to partially support, in conjunction with the High Energy Physics program, operation of the SLAC linac. This will mark the beginning of the transition to LCLS operations at SLAC. The LCLS project will provide the world's first demonstration of an x-ray free-electron-laser (FEL) in the 1.5-15 Å (angstrom) range, 10 billion times greater in peak power and peak brightness than any existing coherent x-ray light source, and that has pulse lengths measured in femtoseconds, the timescale of electronic and atomic motions. The advance in brightness is similar to that of a synchrotron over a 1960's laboratory x-ray tube. Synchrotrons have revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be even more dramatic. The LCLS project leverages capital investments in the existing SLAC linac as well as technologies developed for linear colliders and for the production of intense electron beams with radio-frequency photocathode guns. The availability of the SLAC linac for the LCLS project creates a unique opportunity for demonstration and use of x-ray FEL radiation. The estimated Total Project Cost is $379,000,000.

The FY 2006 budget supports a Major Item of Equipment (MIE) for the Transmission Electron Aberration-corrected Microscope (TEAM). The Total Project Cost is in the range of $25,000,000 to $30,000,000. The TEAM project will construct and operate a new aberration-corrected electron microscope for materials and nanoscience research. The projected improvement in spatial resolution, contrast, sensitivity, and flexibility of design of electron optical instruments will provide unprecedented opportunities to observe directly the atomic-scale order, electronic structure, and dynamics of individual nanoscale structures.

Research to realize the potential of a hydrogen economy will be increased from $29,183,000 to $32,500,000. This research program is based on the BES workshop report *Basic Research Needs for the Hydrogen Economy.* The 2003 report highlights the enormous gap between our present capabilities for hydrogen production, storage, and use and those required for a competitive hydrogen economy. To be economically competitive with the present fossil fuel economy, the cost of fuel cells must be lowered by a factor of five and the cost of producing hydrogen must be lowered by a factor of four. Moreover, the performance and reliability of hydrogen technology for transportation and other uses must be improved dramatically. Simple incremental advances in the present state-of-the-art cannot bridge this gap. Narrowing the gap significantly is the goal of a comprehensive, long-range program of innovative high-risk/high-payoff basic research that is intimately coupled to and coordinated with the DOE's applied programs.

In order to accomplish these very high-priority, forefront activities, some difficult choices had to be made. In particular, the BES support for the Radiochemical Engineering and Development Center at ORNL will be terminated. The operations budgets of the remaining facilities will be at about the same level as in FY 2005, decreasing available beam time and service for users. Core funding for university and national laboratory researchers decreases 7.8 percent compared to the FY 2005 appropriation. While no research activities will be terminated, there will be reductions throughout.

ADVANCED SCIENTIFIC COMPUTING RESEARCH

FY 2005 Comparable Appropriation - $232.5 Million; FY 2006 Request - $207.1 Million

The Advanced Scientific Computing Research (ASCR) program significantly advances scientific simulation and computation, applying new approaches, algorithms, and software and hardware combinations to address the critical science challenges of the future. ASCR also provides access to world-class scientific computation and networking facilities to the Nation's scientific community to support advancements in practically every field of science. ASCR will continue to advance the transformation of scientific simulation and computation into the third pillar of scientific discovery, enabling scientists to look inside an atom or across a galaxy; and inside a chemical reaction that takes a millionth of a billionth of a second or across a climate change process that lasts for a thousand years. In addition, ASCR will shrink the distance between scientists and the resources—experiments, data, and other scientists—they need, and accelerate scientific discovery by making interactions that used to take months happen on a much shorter timescale.

The Mathematical, Information, and Computational Sciences (MICS) effort is responsible for carrying out the primary mission of the ASCR program. In addition, MICS research underpins the success of SciDAC. MICS supports both basic research and the development of the results from this basic research into software usable by scientists in other disciplines. MICS also supports partnerships with scientific discipline users to test the usefulness of the research — facilitating the transfer of research and helping to define promising areas for future research. This integrated approach is critical for MICS to succeed in providing the extraordinary computational and communications tools that DOE's civilian programs need to carry out their missions.

Major elements of the ASCR portfolio related to the SciDAC will be re-competed in FY 2006, with attention paid to support for the long term maintenance and support of software tools such as mathematical libraries, adaptive mesh refinement software, and scientific data management tools developed in the first 5 years of the effort. In addition, in FY 2006 ASCR is changing the way in which it manages its Genomics: GTL partnership with the Biological and Environmental Research program. The management of these efforts will be integrated into the portfolio of successful SciDAC partnerships. The FY 2006 budget request includes $7,500,000 for continued support of the Genomics: GTL research program. The FY 2006 budget request also includes $2,600,000 for the Nanoscale Science, Engineering and Technology initiative led by BES, and $1,350,000 for support of the Fusion Simulation Project, led by the Fusion Energy Sciences program. ASCR's contributions to these partnerships will consist of advancing the mathematics and developing new mathematical algorithms to simulate biological systems and physical systems at the nanoscale. The FY 2006 budget request also provides $8,000,000 to initiate a small number of competitively selected SciDAC institutes at universities which can become centers of excellence in high end computational science in areas that are critical to DOE missions.

The FY 2006 budget also includes $8,500,000 to continue the "Atomic to Macroscopic Mathematics" (AMM) research support in applied mathematics needed to break through the current barriers in our understanding of complex physics processes that occur on a wide range of interacting length- and timescales. Achieving this basic mathematical understanding will provide enabling technology to virtually every challenging computational problem faced by SC.

The National Leadership Computing Facility acquired under the Next Generation Architecture (NGA) Leadership Class Computing Competition in FY 2004 will be operated to provide high performance production capability to selected Office of Science researchers. The NGA effort will play a critical role in enabling Leadership Class Machines that could lead to solutions for scientific problems beyond what would be attainable through a continued simple extrapolation of current computational capabilities. NGA will continue its focus on research in operating systems and systems software and will initiate a new competition for Research and Evaluation Prototype Computer testbeds. ASCR research efforts in Collaboratory Tools and Pilots and Networking will be restructured into an integrated Distributed

Network Environment activity focused on basic research in computer networks and the middleware needed to make these networks tools for science. This change will enable the reduced NGA effort to operate computers acquired in FY 2004 and FY 2005 at the ORNL-Center for Computational Sciences (CCS) as tools for science and especially to satisfy the demand for resources that has resulted from the successful SciDAC efforts.

BIOLOGICAL AND ENVIRONMENTAL RESEARCH

FY 2005 Comparable Appropriation - $581.9 Million; FY 2006 Request - $455.7 Million

The Biological and Environmental Research (BER) program advances energy-related biological and environmental research in genomics and our understanding of complete biological systems, such as microbes that produce hydrogen; develops models to predict climate over decades to centuries; develops science-based methods for cleaning up environmental contaminants; provides regulators with a stronger scientific basis for developing future radiation protection standards; and develops new diagnostic and therapeutic tools, technology for disease diagnosis and treatment, non-invasive medical imaging, and biomedical engineering such as an artificial retina that is restoring sight to the blind.

The FY 2006 budget includes funds for the continued expansion of the Genomics: GTL program—a program at the forefront of the biological revolution. This program employs a systems approach to biology at the interface of the biological, physical, and computational sciences to address DOE's energy, environment, and national security mission needs. This research will continue to more fully characterize the inventory of multi-protein molecular machines found in selected DOE-relevant microbes and higher organisms. It will determine the diverse biochemical capabilities of microbes and microbial communities, especially as they relate to potential biological solutions to DOE needs, found in populations of microbes isolated from DOE-relevant sites. Support for Microbial Genomics research as a separate research activity is terminated to consolidate all microbial research within Genomics: GTL. Support of structural biology, human genome, and health effects research is also reduced to support GTL research. GTL research will provide the scientific community with knowledge, resources, and tools that benefit large numbers of research projects with positive impacts on more scientists and students than are negatively impacted by the initial reduction.

In 2003, the Administration launched the Climate Change Research Initiative (CCRI) to focus research on areas where substantial progress in understanding and predicting climate change, including its causes and consequences, is possible over the next five years. In FY 2006, BER will contribute to the CCRI from four programs: Terrestrial Carbon Processes, Climate Change Prediction, Atmospheric Radiation Measurement (ARM), and Integrated Assessment. Activities will be focused on (1) helping to resolve the magnitude and location of the North American carbon sink; (2) deploying and operating of a mobile ARM Cloud and Radiation Testbed facility to provide data on the effects of clouds and aerosols on the atmospheric radiation budget in regions and locations of opportunity where data are lacking or sparse; (3) using advanced climate models to simulate potential effects of natural and human-induced climate forcing on global and regional climate and the potential effects on climate of alternative options for mitigating increases in human forcing of climate; and (4) developing and evaluating assessment tools needed to study costs and benefits of potential strategies for reducing net carbon dioxide emissions.

The completion of the International Human Genome Project and the transition of BER's Human Genome research program from a human DNA sequencing program to a DNA sequencing user resource for the scientific community which focuses on the sequencing of scientifically important microbes, plants, and animals will bring BER's Human Genome Ethical, Legal, and Societal Issues (ELSI) program to an end. In FY 2006, ELSI research will include activities applicable to Office of Science issues in biotechnology and nanotechnology such as environmental or human health concerns associated with Genomics: GTL or nanotechnology research. Research with these funds will be coordinated across the Office of Science.

BER will focus FY 2006 research activities on higher priorities, including GTL and Climate Change Research, in support of DOE goals and objectives. Funding reductions are initiated in the Environmental Remediation Research subprogram and the Medical Applications and Measurement Science Research subprogram. Accordingly, some current research activities will be phased out in FY 2005. Based on findings of the BER Committee of Visitors for the Environmental Remediation Research subprogram, research activities are integrated into a single program to increase the efficiency of the activities and to better address the BER long term goals in environmental remediation research.

HIGH ENERGY PHYSICS

FY 2005 Comparable Appropriation - $736.4 Million; FY 2006 Request - $713.9 Million

The High Energy Physics (HEP) program provides over 90 percent of the Federal support for the Nation's high energy physics research. This research advances our understanding of dark energy and dark matter, the lack of symmetry in the current universe, the basic constituents of matter, and the possible existence of other dimensions, collectively revealing key secrets of the universe. HEP expands the energy frontier with particle accelerators to study fundamental interactions at the highest possible energies, which may reveal new particles, new forces, or undiscovered dimensions of space and time; explain the origin of mass; and illuminate the pathway to the underlying simplicity of the universe. At the same time, the HEP program sheds new light on other mysteries of the cosmos, uncovering what holds galaxies together and what is pushing the universe apart; understanding why there is any matter in the universe at all; and exposing how the tiniest constituents of the universe may have the largest role in shaping its birth, growth, and ultimate fate.

The HEP program in FY 2006 will continue to lead the world with forefront user facilities producing data that help answer key scientific questions, but these facilities will complete their scientific missions by the end of the decade. Thus, we have structured the FY 2006 HEP program not only to maximize the scientific returns on our investment in these facilities, but also to invest in R&D now for the most promising new facilities that will come online in the next decade. This has required a prioritization of our current R&D efforts to select those which will provide the most compelling science within the available resources. In making these decisions we have seriously considered the recommendations of the High

Energy Physics Advisory Panel (HEPAP) and planning studies produced by the U.S. HEP community. This prioritization process will continue as the R&D programs evolve.

Because of its broad relevance in addressing many of the long-term goals of HEP, and its unique potential for new discoveries, the highest priority is given to the planned operations, upgrades and infrastructure for the Tevatron program at Fermilab. This includes the completion of the upgrade to the Tevatron accelerator complex in 2007 to provide increased luminosity and additional computational resources to support analysis of the anticipated larger volume of data. Over the last few years, the laboratory has developed and implemented a detailed, resource-loaded plan for Tevatron operations and improvements, which has resulted in more reliable luminosity projections. The Office of Science has reviewed the plan and is actively engaged in tracking its progress.

The FY 2006 request supports initial operations of the Neutrinos at the Main Injector (NuMI) project at Fermilab, which has just completed construction and will study the puzzling but fundamental physics of neutrino masses and mixings. The NuMI beam operates in parallel with the Tevatron, also at Fermilab, currently the highest energy accelerator in the world.

In order to fully exploit the unique opportunity to expand our understanding of the asymmetry of matter and antimatter in the universe, a high priority is given to the operations, upgrades and infrastructure for the B-factory at SLAC. Support for B-factory will include an allowance for increased power costs and fully funded upgrades for the accelerator and detector which are currently scheduled for completion in 2006. This includes the completion of the upgrade to the accelerator complex and BaBar detector to provide more data; additional computational resources to support analysis of the larger volume of data; and, increased infrastructure spending to improve reliability. Funding for SLAC operations includes support from the BES program for the LCLS project, marking the beginning of the transition of Linac operations from HEP to BES as B-factory operations are terminated by FY 2008 at the latest.

As the Large Hadron Collider (LHC) accelerator in Europe nears its turn-on date of 2007, U.S. activities related to fabrication of detector components will be completed and new activities related to commissioning and pre-operations of these detectors, along with software and computing activities needed to analyze the data, will ramp-up significantly. Support of a leadership role for U.S. research groups in the LHC physics program will continue to be a high priority for the HEP program.

In order to explore the nature of dark energy, pre-conceptual R&D for potential interagency sponsored experiments with NASA will continue in FY 2006. These experiments will provide important new information about the nature of dark energy and dark matter that will in turn lead to a better understanding of the birth, evolution and ultimate fate of the universe. At this time, no funding for a space-based DOE/NASA Joint Dark Energy Mission past the pre-conceptual stage has been identified.

The engineering design of the BTeV ("B Physics at the Tevatron") experiment, which was scheduled to begin in FY 2005 as a new Major Item of Equipment, is cancelled. This is consistent with the guidance of HEPAP which rated BTeV as of lesser scientific potential than other projects, although still important scientifically and of the Particle Physics Project Prioritization Panel (P5) which supported BTeV but only if it could be completed by 2010, which is not feasible given schedule and funding constraints.

The Linear Collider has been judged to be of the highest scientific importance by HEPAP as well as by scientific advisory bodies of the Asian and European HEP communities. In order to address the opportunity for significant new future research options, R&D in support of an international electron-positron linear collider is increased relative to FY 2005 to support the continued international participation and leadership in linear collider R&D and planning by U.S. scientists.

Recent discoveries and studies have pointed to neutrinos as being an extremely important area of research for deepening our understanding of the nature of matter and the structure of the universe, and HEP is working with the Nuclear Physics program and the National Science Foundation to plan a coordinated program in neutrino physics. To provide a nearer-term future program, and to preserve future research options, R&D for other new accelerator and detector technologies, particularly in the emerging area of neutrino physics, will increase.

NUCLEAR PHYSICS

FY 2005 Comparable Appropriation - $404.8 Million; FY 2006 Request - $370.7 Million

The Nuclear Physics (NP) program is the major sponsor of fundamental nuclear physics research in the Nation, providing about 90 percent of Federal support. NP builds and operates world-leading scientific facilities and state-of-the-art instrumentation to study the evolution and structure of nuclear matter, from the smallest building blocks, quarks and gluons, to the stable elements in the Universe created by stars and to understand how the quarks and gluons combine to form the nucleons (proton and neutron), what are the properties and behavior of nuclear matter under extreme conditions of temperature and pressure, and what are the properties and reaction rates for atomic nuclei up to their limits of stability. Results and insight from these studies are relevant to understanding how the universe evolved in its earliest moments, how the chemical elements were formed, and how the properties of one of nature's basic constituents, the neutrino, influences astrophysics phenomena such as supernovae. Scientific discoveries at the frontiers of nuclear physics further the nation's energy related research capacity, in turn contributing to the Nation's security, economic growth and opportunities, and improved quality of life.

In FY 2006 the NP program will operate world-leading user facilities and make investments that will produce data and develop the research capabilities to achieve the scientific goals discussed above. The Budget Request reflects a balance in on-going facility operations and research support, and investments in capabilities. The FY 2006 budget request provides the resources to operate the program's user facilities at 65 percent of optimum utilization with investments allocated so as to optimize their scientific programs. FY 2006 investments in capital equipment address opportunities identified in the 2002 Long Range Plan of the Nuclear Sciences Advisory Committee (NSAC) and in subsequent recommendations.

In FY 2006 the Relativistic Heavy Ion Collider's (RHIC) beams of relativistic heavy ions will be used by approximately 1000 scientists to continue the exploration of the nature of hot, dense matter and to recreate conditions under which nuclear matter dissolves into the predicted quark-gluon plasma. RHIC started operations in FY 2000 and its first 3 runs have produced over 70 refereed journal papers, creating great interest in the scientific community with the observation of a new state of nuclear matter. In FY 2006 funds are provided for accelerator improvements that will increase accelerator reliability and reduce costs, for detector upgrades needed to characterize the new state of matter observed and for Research and Development to increase the luminosity of the collider. These investments are important for optimizing the scientific research and productivity of the facility. These investments are made at the expense of operating time. FY 2006 funding will support 1,400 hours of operations, a 31 percent utilization of the collider. Effective operation will be achieved by combining FY 2006-FY 2007 running into a single back-to-back run bridging the two Fiscal Years.

Operations of the Thomas Jefferson National Accelerator Facility (TJNAF) in FY 2006 will continue to advance our knowledge of the internal structure of protons and neutrons, the basic constituents of all nuclear matter. By providing precision experimental information concerning the quarks and gluons that form the protons and neutrons, the approximately 1000 experimental researchers, together with researchers in nuclear theory, seek to provide a quantitative description of nuclear matter in terms of the fundamental theory of the strong interaction, Quantum ChromoDynamics. In FY 2006 funds are provided to continue R&D activities for a potential 12 GeV Upgrade of the Continuous Electron Beam Accelerator Facility (CEBAF). These investments will poise the facility for a cost-effective upgrade that would allow insight on the mechanism of "quark confinement"—one of the compelling unanswered puzzles of physics.

In the FY 2006 request funds are provided for the operation of the Argonne Tandem Linac Accelerator System (ATLAS) at ANL and the Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL, for studies of nuclear reactions, structure and fundamental interactions. Included in this funding are capital equipment and accelerator improvement project funds provided to each facility for the enhancement of the accelerator systems and experimental equipment. These low energy facilities will carry out about 80 experiments in FY 2006 involving about 300 U.S. and foreign researchers.

In FY 2006, funds are provided to continue the fabrication of a next generation gamma-ray detector array (GRETINA) and of the Fundamental Neutron Physics Beamline (FNPB) at the Spallation Neutron Source (SNS) that will provide the U.S. with world-leader capabilities in nuclear structure and fundamental neutron studies, respectively. Support continues for completion of the important neutrino experiments at the Sudbury Neutrino Observatory (SNO) and KamLAND.

The research programs at the major user facilities are integrated partnerships between DOE scientific laboratories and the university community, and the planned experimental research activities are considered essential for scientific productivity of the facilities. Funding for university and national laboratory researchers and graduate students decreases 6.8 percent compared to the FY 2005 appropriation.

While we have a relatively good understanding of the origin of the chemical elements in the cosmos lighter than iron, the production of the elements from iron to uranium remains a puzzle. The proposed Rare Isotope Accelerator (RIA) would enable study of exotic nuclei at the very limits of stability, advancing our knowledge of how the elements formed. In FY 2006, R&D activities for the proposed RIA are maintained at the FY 2005 Congressional budget request level.

FUSION ENERGY SCIENCES

FY 2005 Comparable Appropriation - $273.9 Million; FY 2006 Request - $290.6 Million

The Fusion Energy Sciences (FES) program advances the theoretical and experimental understanding of plasma and fusion science, including a close collaboration with international partners in identifying and exploring plasma and fusion physics issues through specialized facilities. This includes: 1) exploring basic issues in plasma science; 2) developing the scientific basis and computational tools to predict the behavior of magnetically confined plasmas; 3) using the advances in tokamak research to enable the initiation of the burning plasma physics phase of the FES program; 4) exploring innovative confinement options that offer the potential of more attractive fusion energy sources in the long term; 5) focusing on the scientific issues of nonneutral plasma physics and High Energy Density Physics (HEDP); and 6) developing the cutting edge technologies that enable fusion facilities to achieve their scientific goals. FES also leads U.S. participation in ITER, an experiment to study and demonstrate the sustained burning of fusion fuel. This international collaboration will provide an unparalleled scientific research opportunity with a goal of demonstrating the scientific and technical feasibility of fusion power.

The FY 2006 request is $290,550,000, an increase of $16,647,000, 6.1 percent over the FY 2005 Appropriation. The FY 2006 budget continues the redirection of the fusion program to prepare for and participate in the ITER project. The ITER International Agreement is currently being negotiated and is expected to be completed by the end of FY 2005. FY 2006 FES funding of $49,500,000 is for the startup of the U.S. Contributions to ITER MIE. The total U.S. Contributions to the ITER MIE, $1,122,000,000, supports the fabrication of the equipment, provision of personnel, limited cash for the U.S. share of common project expenses at the ITER site, and ITER procurements. This MIE is augmented by the technical output from a significant portion of the U.S. Fusion Energy Sciences community research program. Virtually the entire FES program provides related contributions to such ITER relevant research and prepares the U.S. for effective participation in ITER when it starts operations.

Within the overall priorities of the FY 2006 FES budget, $15,900,000 is requested for the National Compact Stellarator Experiment (NCSX), a joint ORNL/Princeton Plasma Physics Laboratory (PPPL) advanced stellarator experiment being built at PPPL. This fusion confinement concept has the potential to be operated without plasma disruptions, leading to power plant designs that are simpler and more reliable than those based on the current lead concept, the tokamak. FY 2006 operation of the three major fusion research facilities will be reduced from a total of 48 weeks to 17 weeks.

FY 2006 funding for the Inertial Fusion Energy/High Energy Density Physics program is $8,086,000, a reduction of $7,255,000 from the FY 2005 level. This will be accomplished by reducing the level of research on heavy ion beams. In addition, the Materials Research program will be eliminated in favor of utilizing the general BES materials effort for scientific advances in areas of fusion interest.

SCIENCE LABORATORIES INFRASTRUCTURE

FY 2005 Comparable Appropriation - $42.0 Million; FY 2006 Request - $40.1 Million

The mission of the Science Laboratories Infrastructure (SLI) program is to enable the conduct of DOE research missions at the Office of Science laboratories by funding line item construction projects to maintain the general purpose infrastructure and the clean up for reuse or removal of excess facilities. The program also supports Office of Science landlord responsibilities for the 24,000 acre Oak Ridge Reservation and provides Payments in Lieu of Taxes (PILT) to local communities around ANL-East, BNL, and ORNL.

In FY 2006, General Plant Projects (GPP) funding is requested to refurbish and rehabilitate the general purpose infrastructure necessary to perform cutting edge research throughout the Office of Science laboratory complex. FY 2006 funding of $3,000,000 is requested to support continued design of the Pacific Northwest National Laboratory (PNNL) Capabilities Replacement Laboratory project. Funding of $11,046,000 is requested to accelerate decontamination and decommissioning (D&D) of the Bevatron Complex at the LBNL.

No funding is requested under the Health and Safety Improvements subprogram to continue health and safety improvements at the Office of Science laboratories identified in the Occupational Safety & Health Administration (OSHA) and Nuclear Regulatory Commission (NRC) reviews. If the Administration determines that health and safety issues remain, resources will be requested in future years as necessary.

SCIENCE PROGRAM DIRECTION

FY 2005 Comparable Appropriation - $153.7 Million; FY 2006 Request - $162.7 Million

Science Program Direction (SCPD) enables a skilled, highly motivated Federal workforce to manage the Office of Science's basic and applied research portfolio, programs, projects, and facilities in support of new and improved energy, environmental, and health technologies. SCPD consists of two subprograms: Program Direction and Field Operations.

The Program Direction subprogram is the single funding source for the Office of Science Federal staff in headquarters responsible for managing, directing, administering, and supporting the broad spectrum of Office of Science disciplines. This subprogram includes planning and analysis activities, providing the capabilities needed to plan, evaluate, and communicate the scientific excellence, relevance, and performance of the Office of Science basic research programs. Additionally, Program Direction includes funding for the Office of Scientific and Technical Information (OSTI) which collects, preserves, and disseminates research and development (R&D) information of the Department of Energy (DOE) for use by DOE, the scientific community, academia, U.S. industry, and the public to expand the knowledge base of science and technology. The Field Operations subprogram is the funding source for the Federal workforce in the Field responsible for management and administrative functions performed within the Chicago and Oak Ridge Operations Offices, and site offices supporting the Office of Science laboratories and facilities.

WORKFORCE DEVELOPMENT FOR TEACHERS AND SCIENTISTS

FY 2005 Comparable Appropriation - $7.6 Million; FY 2006 Request - $7.2 Million

The mission of the Workforce Development for Teachers and Scientists (WDTS) program is to provide a continuum of educational opportunities to the Nation's students and teachers of science, technology, engineering, and mathematics (STEM).

The Scientists Teaching and Reaching Students (STARS) education initiative was launched in FY 2004 to promote science literacy and help develop the next generation of scientists and engineers. In support of this effort, additional FY 2006 funding is requested for both the Laboratory Science Teacher Professional Development (LSTPD) activity and the Middle School Science Bowl. The LSTPD activity is a 3 year commitment experience for K-14 teachers and faculty. The LSTPD will run at five or more DOE national laboratories with about 105 participating STEM teachers, in response to the national need for science teachers who have strong content knowledge in the classes they teach.

The Faculty Sabbatical activity, which is being initiated in FY 2005 for 12 faculty members from Minority Serving Institutions (MSI), will have five positions available in FY 2006. The Faculty Sabbatical is aimed at providing sabbatical opportunities to faculty members from MSIs to facilitate the entry of their faculty into the research funding mainstream. This activity is an extension of the successful Faculty and Student Teams (FaST) program where teams consisting of a faculty member and two or three undergraduate students from colleges and universities with limited prior research capabilities work with mentor scientists at a national laboratory on a research project that is formally documented in a paper or presentation.

In the FY 2006 request, the Pre-Service Teachers (PST) activity will be run at one national laboratory, as opposed to twelve national laboratories in FY 2005, and students will be recruited from participating National Science Foundation (NSF) programs.

SAFEGUARDS AND SECURITY

FY 2005 Comparable Appropriation - $67.2 Million; FY 2006 Request - $68.7 Million

The Safeguards and Security (S&S) program ensures appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or destruction of DOE assets and hostile acts that may cause adverse impacts on fundamental science, national security or the health and safety of DOE and contractor employees, the public or the environment. The SC's Integrated Safeguards and Security Management strategy encompasses a tailored approach to safeguards and security. As such, each site has a specific protection program that is analyzed and defined in its individual Security Plan. This approach allows each site to design varying degrees of protection commensurate with the risks and consequences described in their site-specific threat scenarios.

The FY 2006 request meets minimum, essential security requirements. Protection of employees and visitors is of primary concern, as well as protection of special nuclear material and research facilities, equipment and data. Priority attention is given to protective forces, physical security systems, and cyber security.

CONCLUSION

The Office of Science occupies a unique and critical role within the U.S. scientific enterprise. We fund research projects in key areas of science that our Nation depends upon. We construct and operate major scientific user facilities that scientists from virtually every discipline are using on a daily basis, and we manage civilian national laboratories that are home to some of the best scientific minds in the world.

Madame Chairman, we have made some difficult decisions this year within the President's budget request for the Office of Science—consistent with our research priorities—which will allow us to build on the solid foundation created over the last four years, propel us into new areas of great scientific promise, and maintain America's world-class stature in science.

I want to thank you, Madame Chairman, for providing this opportunity to discuss the Office of Science research programs and our contributions to the Nation's scientific enterprise. On behalf of DOE, I am pleased to present this FY 2006 budget request for the Office of Science.

This concludes my testimony. I would be pleased to answer any questions you might have.

Raymond L. Orbach
Director,
Office of Science

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Dr. Raymond L. Orbach was sworn in as the 14th Director of the Office of Science at the Department of Energy (DOE) on March 14, 2002. As Director of the Office of Science (SC), Dr. Orbach manages an organization that is the third largest Federal sponsor of basic research in the United States and is viewed as one of the premier science organizations in the world. The SC fiscal year 2005 budget of $3.6 billion funds programs in high energy and nuclear physics, basic energy sciences, magnetic fusion energy, biological and environmental research, and computational science. SC, formerly the Office of Energy Research, also provides management oversight of the Chicago and Oak Ridge Operations Offices and 10 DOE non-weapons laboratories.

Prior to his appointment, Dr. Orbach served as Chancellor of the University of California (UC), Riverside from April 1992 through March 2002; he now holds the title Chancellor Emeritus. During his tenure as Chancellor, UC Riverside grew from the smallest to one of the most rapidly growing campuses in the UC system. Enrollment increased from 8,805 to more than 14,400 students with corresponding growth in faculty and new teaching, research, and office facilities.

In addition to his administrative duties at UC Riverside, Dr. Orbach maintained a strong commitment to teaching. He sustained an active research program; worked with postdoctoral, graduate, and undergraduate students in his laboratory; and taught the freshman physics course each winter quarter. As Distinguished Professor of Physics, Dr. Orbach set the highest standards for academic excellence. From his arrival, UC Riverside scholars led the nation for seven consecutive years in the number of fellows elected to the prestigious American Association for the Advancement of Science (AAAS).

Dr. Orbach began his academic career as a postdoctoral fellow at Oxford University in 1960 and became an assistant professor of applied physics at Harvard University in 1961. He joined the faculty of the University of California, Los Angeles (UCLA) two years later as an associate professor, and became a full professor in 1966. From 1982 to 1992, he served as the Provost of the College of Letters and Science at UCLA.

Dr. Orbach's research in theoretical and experimental physics has resulted in the publication of more than 240 scientific articles. He has received numerous honors as a scholar including two Alfred P. Sloan Foundation Fellowships, a National Science Foundation Senior Postdoctoral Fellowship, a John Simon Guggenheim Memorial Foundation Fellowship, the Joliot Curie Professorship at the Ecole Superieure de Physique et Chimie Industrielle de la Ville de Paris, the Lorentz Professorship at the University of Leiden in the Netherlands, and the 1991-1992 Andrew Lawson Memorial Lecturer at UC Riverside. He is a fellow of the American Physical Society and the AAAS.

Dr. Orbach has also held numerous visiting professorships at universities around the world. These include the Catholic University of Leuven in Belgium, Tel Aviv University, and the Imperial College of

Science and Technology in London. He also serves as a member of 20 scientific, professional, or civic boards.

Dr. Orbach received his Bachelor of Science degree in Physics from the California Institute of Technology in 1956. He received his Ph.D. degree in Physics from the University of California, Berkeley, in 1960 and was elected to Phi Beta Kappa.

Dr. Orbach was born in Los Angeles, California. He is married to Eva S. Orbach. They have three children and seven grandchildren.